Documentation of the GTAP-EUCalc model and Portfolio of GTAP-EUCalc Pathways

D7.4

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Explore sustainable European futures

Documentation of the GTAP-EUCalc model and Portfolio of GTAP-EUCalc Pathways

D7.4

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Short Description
Using outputs from tasks 7.1 to 7.3 we developed a version of the GTAP model/database (GTAP-EUCalc) specifically tailored to be able to run scenarios aiming at evaluating the transboundary effects of the lever results obtained from WPs 1-5 and to deliver these results as usable outputs by the EU Calculator. Transboundary effects include EU28+Switzerland trade balance, aggregated and for specific sectors, composition of intra-EU and extra-EU trade by MS, EU28+Switzerland carbon leakage. *In this deliverable, we describe in details the specific version of the GTAP-E model and database developed for the EUCalc project, and a library of different GTAP-EUCalc pathways to be simulated using the GTAP-EUCalc model, and the types of results of which are to be plugged into the Transition Pathway Explorer.*

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Name of reviewer	**Date**
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Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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List of abbreviations

BAU:	Business As Usual
CD:	Cobb Douglas
CDE:	Constant difference of elasticities
CES:	Constant elasticity of substitution
CGE:	Computable General Equilibrium
EU:	European Union
EU28:	European Union, 28 countries
EUCalc:	European Calculator
Gg:	Giga gram
GTAP:	Global Trade Analysis Project
GWP:	Global Warming Potential
IPCC:	Intergovernmental Panel on Climate Change
LTS:	Long Term Strategy
MS:	Member State
Mt:	Mega Tonne
ROW:	Rest Of the World
SSP:	Shared Socio-economic Pathway
TFP:	Total Factor Productivity
TPE:	Transition Pathway Explorer
WP:	Work Package
WTO:	World Trade Organization

Executive summary

This deliverable describes the work carried out in WP7. It introduces the need for a general equilibrium framework in order to analyze transboundary effects of different EU decarbonization pathways in 2050. Within this framework, a CGE model is specifically built for the EUCalc project (named GTAP-EUCalc). This model is developed based on the architecture of the standard GTAP-E model, and documented in this report. Following D7.1 and part of the discussions held in the expert workshops (D7.3), the finalized version of the 2050 economic baseline, against which trade effects of decarbonization pathways are simulated, is delineated. The final part of this report focuses on the library of scenarios/pathways derived from EUCalc core modules to be simulated in GTAP-EUCalc and on how the substantial amount of results generated by the CGE model is processed in order to obtain user-friendly readable trade results to be shown in the Transition Pathway Explorer.

1 Module introduction

The module based on the research performed by the work package on "Transboundary Effects and Trade Flows" (WP7 hereafter), within the EUCalc project, aims at quantifying the transboundary effects of user-selected decarbonization pathways, defined at sectoral levels and obtained from combinations of levers[a] from other EUCalc modules. Trade effects are generated by using a computable general equilibrium (CGE) modelling framework that simulates perturbations to a projected baseline of the world economy in 2050. The simulated transboundary effects will inform EUCalc users of likely future economic dependencies inside the EU28+Switzerland as well as between the EU28+Switzerland and the rest of the world (ROW) due to the decarbonization efforts of EU28+Switzerland.

Transboundary flows refer to the trade of goods and services amongst the EU28+Switzerland, as well as between the EU28+Switzerland and the rest of the world. As the envisioned decarbonization pathways impose changes in both demand and supply, levels and structures of production and consumption of sectors and countries are also altered. This, in turn, changes the economic dependences concerning the aforementioned countries at sectoral levels and leads to modifications in trade patterns. Furthermore, as transboundary flows of goods and services also embody energy consumption and GHG emissions, projecting transboundary flows is an important consideration in evaluating the options and tradeoffs of decarbonization pathways for the EU28+Switzerland and their "emission effectiveness" in a global context.

Modeling the transboundary effects mandates the use of an economic modeling system that takes into consideration not only inter-sectoral linkages, such as the input-output associations connecting raw materials and fossil fuels to final outputs, but also linkages through the competition/allocation of available economic resources such as labor and capital. Additionally, the EU28+Switzerland and other ROW economies must be connected in the model such that imbalances between demand and supply at sectoral levels for each country can be accounted for via transboundary trade flows. Essentially, this requires the use of a global CGE model focused on trade linkages. In fact, CGE models are a typical tool for empirical analysis of distributional and welfare impacts of different policies (Winters and Hertel, 2005, Anderson and Martin, 2005, Bourne and Philippidis, 2018). More generally, they can be used to measure the result of shocks to an economic system (i.e. computable), encompassing simultaneously all economic activities (consumption, production, employment, taxes, savings, trade etc.) and the linkages among them (i.e. general), in an economy where at a given set of prices all agents are satisfied (i.e. equilibrium) (Burfisher, 2011). To analyze the trade and transboundary effects of EUCalc decarbonization pathways, this module adopts a modified version of the GTAP-E model (Burniaux and Truong, 2002, McDougall and Golub, 2007), nicknamed GTAP-EUCalc.

As noted in Deliverable 7.2 of the EUCalc project (Baudry et al., 2018), static CGE models including the GTAP models have several limitations in simulating long term scenarios where large structural changes in behaviors and technologies are

[a] Levers represent different GHG abatement ambition levels with respect to behavior, technology or practices patterns in different sectors, which the EUCalc model's user can modify to formulate their own decarbonization pathways and visualize the results of their choices on a web interface.

expected, as is the case of the ambitious EUCalc pathways formulated from its core modules. To overcome these limitations, the GTAP-EUCalc model incorporates several key modifications, as summarized below:

1. Modify the structure of the GTAP-E model for the scope of EUCalc, i.e. to project the world economy to the year 2050, to accommodate the sectoral coverages of other EUCalc WPs, and to design new model structures to facilitate the implementation of the large structural shocks implied by the sectoral lever settings. The new model, nicknamed GTAP-EUCalc, is presented in this document;
2. Construct a baseline projection of the world economy for 2050. The data chosen to project the GTAP-9 database are introduced in Deliverable 7.1 (Yu and Clora, 2018). In this deliverable, we describe the final refinements and modeling choices in regard to the 2050 economic baseline;
3. Design an interface to facilitate the transformation of alternative sectoral EUCalc pathways as inputs into the GTAP-EUCalc model, in order to simulate the transboundary effects. The interface design process and description are addressed in Deliverables D7.2 (Baudry et al., 2018) and D8.6 (Clora and Yu, 2019);
4. Simulate the alternative EUCalc pathways as model scenarios, to generate the transboundary effects to be included in the EUCalc Transition Pathway Explorer (TPE). A library of pathways to be simulated in GTAP-EUCalc is presented in this report.

The document is structured as follow. Section 2 introduces the GTAP-EUCalc model and database. Section 3 presents the 2050 economic baseline projection exercise. Section 4 introduces the sets of scenarios to be simulated in GTAP-EUCalc. Section 5 displays and describes the module's core outputs.

2 The GTAP-EUCalc model

Trade and transboundary effects of EUCalc decarbonization pathways are simulated and analyzed by adopting a modified version of the GTAP-E model (McDougall and Golub, 2007, Burniaux and Truong, 2002), which is the energy-environmental version of the GTAP model (Hertel et al., 1997). A model (nicknamed "GTAP-EUCalc") has been developed, adapting the GTAP-E version 6-pre2 (McDougall and Golub, 2007) to the scope of the EUCalc.

2.1 The GTAP framework

The GTAP model is among the most widely used CGE models. GTAP's extensive country coverage and its general equilibrium modelling structure on sectoral and trade linkages within and across countries complement the scope of the EUCalc as it allows for simulating the transboundary effects of alternative EUCalc pathways under various lever settings.

The GTAP framework[b] at its core consists of a database and a standard model on which multiple models have been developed. The dataset contains

[b] For more information, visit www.gtap.org

national/regional input-output tables that are linked through bilateral trade flows, transport, and protection linkages. The GTAP-9 database (Aguiar et al., 2016) characterizes the world economy, with the available benchmark years being 2011, 2007 and 2004. It includes data on consumption, production, trade, energy and CO2 emissions. The GTAP-9 database includes 140 regions, 57 tradable commodities, and 5 non-tradable primary factors. The values in the GTAP-9 database are all presented in millions of (2004, 2007 and 2011) current USD. Carbon dioxide emissions are displayed by region, commodity, and use. In detail, the current GTAP database differentiates emissions from households and government consumption of domestic and imported products, and emissions from firms' usage of domestic and imported intermediate goods. The values are expressed in mega-tonnes of CO2 (Mt CO2).

We also use the GTAP satellite non-CO2 emissions database, developed by Irfanoglu and van der Mensbrugghe (2015) based on the work of Rose and Lee (2008). It includes non-CO2 emissions by region and sector, for the three main non-CO2 gases, i.e. CH4, N2O and a cluster encompassing fluorinated gases ('F-gases'). Emissions are generated by four drivers: final private consumption, intermediate consumption, endowment use (capital and land), and output. Unlike the standard GTAP database, no distinction between consumption of imported and domestically produced commodities is specified. Data are provided both in giga-grams (Gg) and MtCO2e. The global warming potentials adopted to convert giga-grams of each non-CO2 gas into CO2e are shown in table 2.1. Such values are consistent with IPCC (2014).

Table 2.1 - Global warming potentials[c] of GHG gases, for a time horizon of 100 years, used in GTAP-9 satellite non-CO2 emissions database

Gas	**GWP**
CO2	1
CH4	21
N2O	310
CF4	6500
SF6	23900
HFC-22	11700
HFC-234a	1300

The standard GTAP model (Hertel et al., 1997) – on which the GTAP-E model is built - is a static multi-region/country, multi-sector CGE model, with perfectly competitive markets and constant returns to scale technologies. It includes treatment of private household behavior, government expenditure, international trade and transport activity, and global investments/savings relationship.

[c] The Global Warming Potential represents how much of a given mass of a gas contributes to global warming, over a given time period, compared to the same mass of carbon dioxide, chosen as a benchmark.

The underlying system of equations in the GTAP model includes two types of equations: accounting (identity) relationships, ensuring that revenues and expenditures of every agent in the economy are equalized, and behavioral equations, specifying the behavior of optimizing agents (i.e. consumers and producers) in the economy when they have to modify their optimal choices in the presence of shocks (Brockmeier, 2001).

Figure 2.1 depicts the core structure of the GTAP model, focusing on the accounting relationships, and allows to visualize the flows and linkages. For a clearer representation, the figure only shows the value flows within the economy; the corresponding factors/inputs/commodity flows in the opposite direction are not displayed.

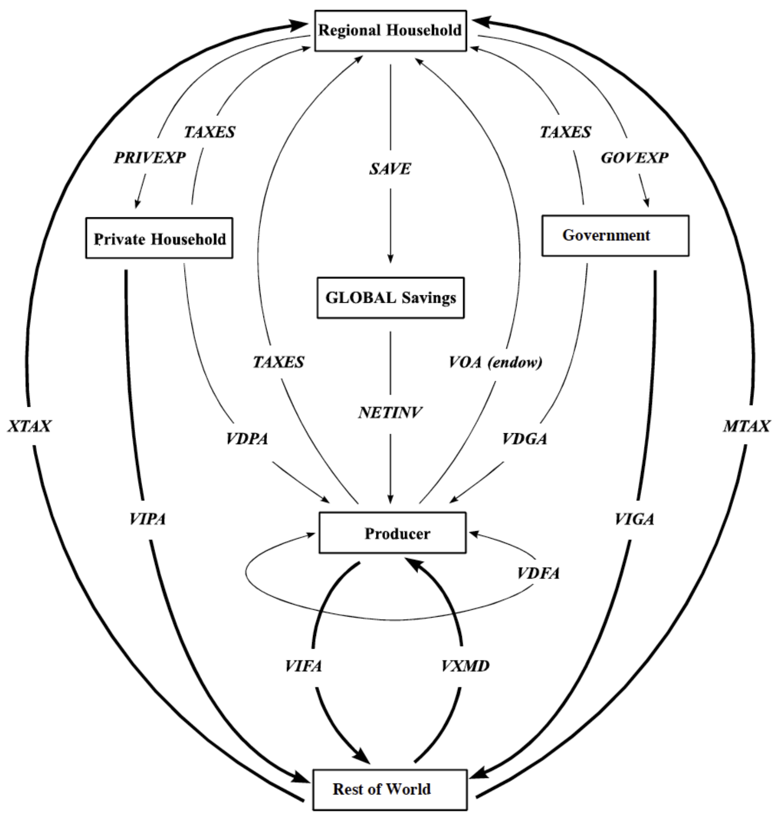

Figure 2.1 - GTAP structure (Brockmeier, 2001)

PRIVEXP: private consumption expenditure in region r; VDPA: domestic purchases, by households, at agents' prices; VIPA: import purchases, by households, at agents' prices; GOVEXP: government consumption expenditure in region r; VDGA: domestic purchases, by government, at agents' prices; VIGA: import purchases, by government, at agents' prices; SAVE: net saving, by region; NETINV: regional net investment; VOA: value of commodity i output in region r at agents' prices; VDFA: domestic purchases, by firms, at agents' prices; VIFA: import purchases, by firms, at agents' prices; VXMD: Non-margin exports, at market prices; TAXES: different kind of taxes or subsidies; MTAX: tax on imports on good i from source r in destination s; XTAX: tax on exports on good i from source r in destination s.

The household associated with each region collects all the income generated in each regional economy, and fully consumes it over government expenditures, private expenditures and savings, according to a Cobb-Douglas (CD) per capita utility function. Domestic government purchases at agent's price are modeled according to a CD sub-utility function, with constant expenditures across all commodities. Savings are entirely consumed on investment. In GTAP, domestic private consumption is represented by the Constant Difference of Elasticity (CDE) implicit expenditure function. The producers receive payments from selling final consumption goods, intermediate inputs to other producers, and from investment goods to the global saving sector. These revenues are used on expenditures for primary factors of production and for intermediate inputs, given the zero-profit assumption.

Additionally to the closed economy described in the paragraph above, the GTAP model represents also policy interventions, and linkages among the various economies in the world. Taxes are paid by firms, government and private consumers to the regional household, and are captured by a wedge between agent's prices (including the tax) and market prices. For international trade, a two-tier "Armington" structure (Armington, 1969) is specified to allow for imperfect substitutions between imports and domestically produced products, as well as between imports from different sourcing countries. This structure enables the model to track both imports and exports between any given pair of importing and exporting countries (see figure 2.2). Tariffs are paid on imports, by firms, the private agent and the government. Imported and domestic commodities are combined in a composite nest for the private and government households, in a fashion similar to the firms production tree. Household's and firms' import demands differ only in their import shares, since the elasticity of substitution between imported and domestic goods in the composite nest of the utility tree is assumed to be equal across uses.

Zooming in the production structure, an intuitive way to describe it is through a 'production tree', shown in figure 2.2. Each node of the tree symbolizes a composite intermediate commodity or a primary factor, resulting as an aggregate of the commodities and factors included one level below. An appropriate input demand in each node of the production structure results from cost minimization behavior from firms.

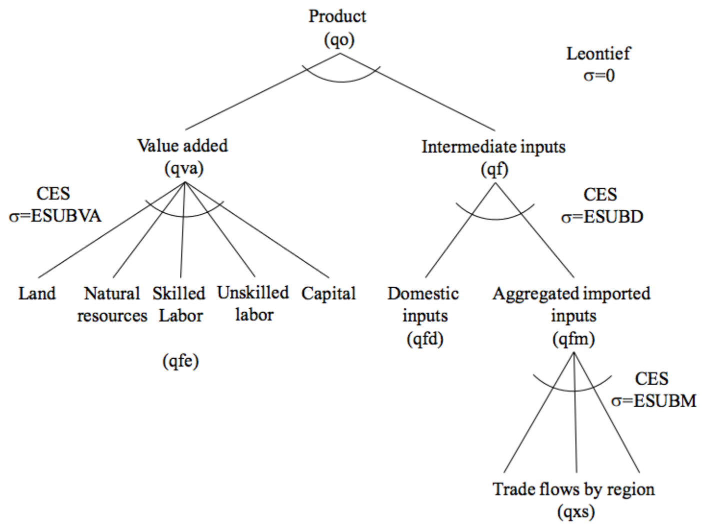

Figure 2.2 - Production structure in the standard GTAP model

Firms purchase intermediate inputs that are either domestically produced or imported. Imported inputs are aggregated by a constant elasticity of substitution (CES) production function. Likewise, a CES production function regulates the grouping of domestic intermediate inputs and combined imported ones. In the other intermediate nest, endowment commodities are aggregated through a CES function, generating the value-added nest. The primary production factors are fully employed within each region, and cannot migrate between regions. In the final step, the value added nest is combined with intermediate inputs through a Leontief production function, in order to generate output, implying an elasticity of substitution between bundled intermediate inputs and primary factors equal to zero. Given the assumption of constant returns to scale and the Leontief production function in the highest production nest, firms choose their optimal mix of primary factors independently from intermediate inputs' prices. Furthermore, within the value-added nest, the factors are perfectly mobile, earning the same market returns across sectors, and endowments sluggish to adjust, earning differential returns (Hertel et al. 1997).

The GTAP-E model differs from the standard GTAP model mainly because it adds an explicit capital-energy composite input into the production structure (figure 2.3), allowing for a degree of capital-energy substitution (Burniaux and Truong, 2002). In addition, it comprises a different treatment of energy demand, inter-fuel substitution, CO2 accounting, taxation and regional emission trading. In GTAP-E, the final consumption structure is altered too. Government consumption is based on a CD structure, and energy commodities are separated from the others by a CES structure. The household private consumption structure is the same as in the standard GTAP model, and adopts the CDE functional form. However, in the second-level nest, an energy composite using a CES functional form is specified.

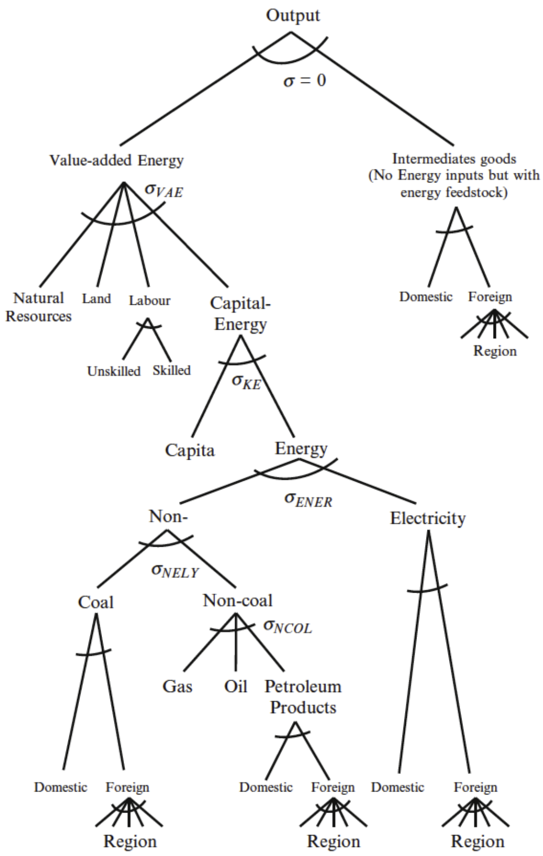

Figure 2.3 - GTAP-E production structure

For the scope of EUCalc, a modified version of the GTAP-E model (McDougall and Golub, 2007, Burniaux and Truong, 2002) has been developed, including several key modifications to the standard GTAP-E model that are documented in the next section.

2.2 Key features of GTAP-EUCalc

The GTAP-EUCalc model differs from its predecessor (GTAP-E) by incorporating an aggregate land supply function, a new private demand system with two embedded within-budget share shifters to target changes consumption shares, a twist parameter in each nest of the CES firms' structure, and additional sets of equations accounting for non-CO2 emissions and overall GHG emissions. In the following paragraphs, the main differences and modifications with respect to GTAP-E are described.

2.2.1 Two alternative private demand systems

Two alternative private demand systems are used. The standard CDE functional form, first proposed by Hanoch (1975), is used for projecting the GTAP-9 database from 2011 to 2050. This system is robust and regular globally[d] with very significant income increases (Yu et al., 2004), and is widely used in CGE models since the work of Hertel et al. (1991). In fact, it allows for differences in both price and income responsiveness of demand in different regions, contingent on the development level and observed consumption patterns in that region. However, such a complex system is not easily reparametrized for purposes of generating the very large demand structural changes implied by many of the assumed lifestyle levers in WP1. In fact, pre-trials of selected demand shocks from the relevant EUCalc modules cannot be solved without changing the underlying consumer preferences behind the CDE demand system. Therefore, to simulate decarbonization pathways in 2050, the CDE is substituted by a CD demand system. In practice, this is done in GTAP-E by setting the expansion parameter equal to 1 and the substitution parameter equal to 0. Under homothetic preferences, income elasticities are unitary and budget shares are constant, regardless of the income levels.

2.2.2 Twist parameters

To simulate lifestyle changes as defined by the EUCalc Lifestyle module, two within-budget share shifters have been introduced in the private demand nests. The first shifter is implemented in the CES energy private consumption nest and allows to modify consumption between coal, oil, gas, oil products and electricity. The second shifter is added to the CD upper consumption nest, allowing for exogenous preference-driven changes across the energy bundle and the non-energy commodities. Thanks to these shifters, designed similarly to Dixon and Rimmer (2002), it is possible to represent EUCalc-derived modifications to the private demand for energy and non-energy commodities based on preference changes with relative ease.

Similarly to the within-budget shifter, a twist-parameter in each nest of the CES production structure allowing for changes in cost shares is added to the model, as

[d] The "regularity requirements are related to the properties of the expenditure function. An expenditure function is considered regular if its value is non-negative, its first derivatives with respect to prices (compensated demands) are non-negative, and if the matrix of second partial derivatives with respect to prices is negative semi-definite (implied by the concavity property). The non-negativity requirement, coupled with the adding-up property, requires that the budget share of the good should lie in the [0,1] interval. In long run projections, with considerable changes in income/expenditure, this requirement is crucial in ensuring the demand system behaves in accordance with economic theory." (Yu et al., 2004)

proposed by Dixon and Rimmer (2002) and applied, among others, by WTO (2018). This implementation is performed to facilitate the modeling of changes in technologies in many of the EUCalc sectors, according to their lever settings.

2.2.3 Aggregate land supply function

The model also features an isoelastic aggregate supply of land to allow for aggregated land supply responses by country/region. The land price elasticities are econometrically estimated by Philippidis et al. (2017), and shown in table 2.4 below. In the GTAP-EUCalc code, the land supply function is implemented with an approach similar to the one developed by Kløverpris and Baltzer (2008).

Table 2.2 - Aggregate land price elasticity of supply (ELND), estimated at the country level

Country	ELND	Country	ELND	Country	ELND
Austria	0.027	France	0.015	Malta	0.015
Belgium	0.035	United Kingdom	0.015	Netherlands	0.015
Bulgaria	0.015	Greece	0.015	Poland	0.141
Cyprus	0.112	Croatia	0.04	Portugal	0.015
Czech Republic	0.015	Hungary	0.016	Romania	0.041
Germany	0.218	Ireland	0.015	Slovakia	0.015
Denmark	0.015	Italy	0.025	Slovenia	0.015
Spain	0.015	Lithuania	0.009	Sweden	0.015
Estonia	0.065	Luxembourg	0.015	Switzerland	0.015
Finland	0.015	Latvia	0.014		

2.2.4 GHG accounting equations

A set of accounting equations for non-CO2 emissions and for overall GHG emissions is added. Owing to the different structures of the CO2 and non-CO2 GTAP9 databases, some assumptions are necessary. In GTAP-E, carbon emissions are shown by country/region, commodity and use (private demand, government demand, intermediate demand), with a distinction between domestically produced and imported goods. They are assumed to be proportional to uses of fossil fuels. Non-CO2 emissions, as mentioned above, are generated by private and intermediate consumption, endowment use (capital and land), and outputs. Differently from the CO2 database, the non-CO2 database accounts for emissions generated not only by fossil fuel usage, but also by industries' production processes (e.g. fugitives from mining activities, landfilling of solid waste, use of ozone depleting substances substitutes) and by agriculture (e.g. livestock enteric fermentation, manure management, fertilizers use). Additionally, emissions caused by private and intermediate consumption are not differentiated by origin. These differences are addressed in the new set of equations written to incorporate non-CO2 emissions in GTAP-EUCalc. In fact, we assume a linear relationship between non-CO2 emissions and their drivers, implicitly distinguishing emissions due to the consumption of imported and domestically produced products. Furthermore, a set of equations to account for total GHG emissions at the sectoral and regional levels is defined. These equations allow us to generate a measure of GHG emitted per commodity produced, which in turn permits to track GHG embedded in bilateral trade flows.

2.3 Country and sectoral aggregations in GTAP-EUCalc

The core data used for model simulations with GTAP-EUCalc is the GTAP database version 9 (Aguiar et al., 2016) encompassing 140 countries/regions and 57 sectors, supplemented with satellite data on CO2 and non-CO2 emission data (Irfanoglu and van der Mensbrugghe, 2015). For the specific purposes of the EUCalc project, the GTAP database has been aggregated to match the sectoral and regional aggregation of the EUCalc modules, taking into account their economic sensibility and the simulations' solvability. The aggregations are presented in table 2.3 and table 2.4.

On the country dimension, two similar (yet different) aggregations are implemented. When projecting the 2050 economic baseline, the EU28 MSs and Switzerland are not aggregated. This first aggregation allows to achieve consistency with the GDP projections and its main drivers gathered in D7.1 (Yu and Clora, 2018), and to fully capture the linkages between the EU countries, without hampering the model computability. When simulating the EUCalc pathways, EU28 MSs and Switzerland are aggregated into 17 countries/regions, as shown in table 2.3. The rest of the world, not modeled by EUCalc core modules, is combined into 15 countries/regions in both aggregations, as reported in table 2.3. This aggregation is necessary to reduce the possibility of not being able to solve the model, nevertheless allowing to capture the main regional impacts of decarbonization pathways.

Table 2.3 - GTAP-EUCalc regional aggregation

GTAP-EUCalc region	GTAP region
Austria (aut)	Austria (AUT)
Germany (deu)	Germany (DEU)
Denmark (dnk)	Denmark (DNK)
Spain (esp)	Spain (ESP)
Finland (fin)	Finland (FIN)
France (fra)	France (FRA)
UK (gbr)	UK (GBR)
Ireland (irl)	Ireland (IRL)
Italy (ita)	Italy (ITA)
Netherlands (nld)	Netherlands (NLD)
Poland (pol)	Poland (POL)
Portugal (prt)	Portugal (PRT)
Slovakia (svk)	Slovakia (SVK)
Sweden (swe)	Sweden (SWE)
Belgium and Luxembourg (belux)	Belgium (BEL), Luxembourg (LUX)
Balkans, South and South-East Europe (bk_s_se_eu)	Bulgaria (BGR), Cyprus (CYP), Greece (GRC), Croatia (HRV), Malta (MLT), Romania (ROU), Slovenia (SVN)
Baltics and Central Europe (btc_c_eu)	Czech Republic (CZE), Estonia (EST), Hungary (HUN), Lithuania (LTU), Latvia (LVA), Slovakia (SVK)
Switzerland (che)	Switzerland (CHE)
Rest of Europe (r_eur)	Norway (NOR), Rest of EFTA (XEF), Albania (ALB), Ukraine (UKR), Rest of Eastern Europe (XEE), Rest of Europe (XER)

Russia (rus)	Russia (RUS)
Rest of ex-USSR (fsu)	Kazakhstan (KAZ), Tajikistan (TJK), Azerbaijan (AZE), Belarus (BLR), Georgia (GEO), Kyrgyzstan (KGZ), Rest of Former Soviet Union (XSU), Armenia (ARM)
China (chn)	China (CHN)
India (ind)	India (IND)
High-Income South-East Asia (hi_sea)	Hong Kong (HKG), Japan (JPN), Korea (KOR), Taiwan (TWN), Singapore (SGP)
Rest of South-East Asia and Pacific (r_sea_p)	Rest of Oceania (XOC), Mongolia (MNG), Rest of East Asia (XEA), Brunei Darussalam (BRN), Cambodia (KHM), Indonesia (IDN), Laos (LAO), Malaysia (MYS), Philippines (PHL), Thailand (THA), Viet Nam (VNM), Rest of Southeast Asia (XSE), Bangladesh (BGD), Nepal (NPL), Pakistan (PAK), Sri Lanka (LKA), Rest of South Asia (XSA)
Australia and New Zealand (aus_nz)	Australia (AUS), New Zealand (NZL)
Middle East and North Africa (mena)	Israel (ISR), Bahrain (BHR), Iran (IRN), Kuwait (KWT), Oman (OMN), Qatar (QAT), Saudi Arabia (SAU), United Arab Emirates (ARE), Rest of Western Asia (XWS), Rest of North Africa (XNF), Jordan (JOR), Turkey (TUR), Egypt (EGY), Morocco (MAR), Tunisia (TUN)
Rest of Africa (r_afr)	Benin (BEN), Burkina Faso (BFA), Cameroon (CMR), Côte d'Ivoire (CIV), Ghana (GHA), Guinea (GIN), Nigeria (NGA), Senegal (SEN), Togo (TGO), Rest of Western Africa (XWF), Central Africa (XCF), South-Central Africa (XAC), Ethiopia (ETH), Kenya (KEN), Madagascar (MDG), Malawi (MWI), Mauritius (MUS), Mozambique (MOZ), Rwanda (RWA), Tanzania (TZA), Uganda (UGA), Zambia (ZMB), Zimbabwe (ZWE), Rest of Eastern Africa (XEC), Botswana (BWA), Namibia (NAM), South Africa (ZAF), Rest of South African Customs Union (XSC), Rest of the World (XTW)
USA (usa)	United States (USA)
Canada and rest of North America (cnd_na)	Canada (CAN), Rest of North America (XNA)
Mexico (mex)	Mexico (MEX)
Brazil (bra)	Brazil (BRA)
Rest of Latin America (r_lam)	Argentina (ARG), Chile (CHL), Paraguay (PRY), Peru (PER), Uruguay (URY), Rest of South America (XSM), Costa Rica (CRI), Guatemala (GTM), Honduras (HND), Nicaragua (NIC), Panama (PAN), El Salvador (SLV), Rest of Central America (XCA), Dominican Republic (DOM), Jamaica (JAM), Puerto Rico (PRI), Trinidad and Tobago (TTO), Rest of Caribbean (XCB), Bolivia (BOL), Colombia (COL), Ecuador (ECU), Venezuela (VEN)

On the sectoral dimension, the 57 GTAP sectors are aggregated into 17, in order to represent the EUCalc classifications. Similarly to the regional aggregation, this allows to capture sectoral interactions and heterogeneities while owing to the model complexities.

Table 2.4 - GTAP-EUCalc sectoral aggregation and EUCalc sectoral mapping

<table>
<tr><th>GTAP-EUCalc sector</th><th>GTAP sector</th><th>EUCalc sector</th></tr>
<tr><td>Crops (crops)</td><td>Paddy rice (PDR); Wheat (WHT); Cereal grains nec (GRO); Vegetables, fruit, nuts (V_F); Oil seeds (OSD); Sugar cane, sugar beet (C_B); Plant-based fibers (PFB); Crops nec (OCR)</td><td>WP1 (lifestyles), WP4 (crops)</td></tr>
<tr><td>Livestock (lvstck)</td><td>Bovine cattle, sheep and goats, horses (CTL); Animal products nec (OAP); Raw milk (RMK); Wool, silk-worm cocoons (WOL)</td><td>WP4 (livestock)</td></tr>
<tr><td>Rest of extraction (r_ext)</td><td>Forestry (FRS); Fishing (FSH); Minerals nec (OMN)</td><td>WP4 (Forestry, Land Use and Land Use Change, Agriculture, Minerals)</td></tr>
<tr><td>Animal-based food (f_anm)</td><td>Bovine meat products (CMT); Meat products nec (OMT); Dairy products (MIL)</td><td rowspan="2">WP1 (lifestyles), WP4 (food production)</td></tr>
<tr><td>Non animal-based food (f_n_anm)</td><td>Vegetable oils and fats (VOL); Processed rice (PCR); Sugar (SGR); Food products nec (OFD); Beverages and tobacco products (B_T)</td></tr>
<tr><td>Gas (gas)</td><td>Gas (GAS); Gas manufacture, distribution (GDT)</td><td rowspan="5">WP5 (energy)</td></tr>
<tr><td>Coal (coal)</td><td>Coal (COA)</td></tr>
<tr><td>Oil (oil)</td><td>Oil (OIL)</td></tr>
<tr><td>Oil products (oil_pcts)</td><td>Petroleum, coal products (P_C)</td></tr>
<tr><td>Electricity (electricity)</td><td>Electricity (ELY)</td></tr>
<tr><td>Manufacture (mnf)</td><td>Mineral products nec (NMM); Ferrous metals (I_S); Metals nec (NFM); Metal products (FMP); Wood products (LUM); Paper products, publishing (PPP); Textiles (TEX); Wearing apparel (WAP); Leather products (LEA); Motor vehicles and parts (MVH); Transport equipment nec (OTN); Electronic equipment (ELE); Machinery and equipment nec (OME); Manufactures nec (OMF)</td><td rowspan="2">WP3 (manufacture)</td></tr>
<tr><td>Chemical products (crp)</td><td>Chemical, rubber, plastic products (CRP)</td></tr>
<tr><td>Road and rail transport (otp)</td><td>Transport nec (OTP)</td><td rowspan="3">WP2 (transportation)</td></tr>
<tr><td>Water transport (wtp)</td><td>Water transport (WTP)</td></tr>
<tr><td>Air transport (atp)</td><td>Air transport (ATP)</td></tr>
<tr><td>Dwellings (dwe)</td><td>Dwellings (DWE)</td><td>WP2 (buildings)</td></tr>
<tr><td>Services (serv)</td><td>Water (WTR); Trade (TRD); Construction (CNS); Communication (CMN); Financial services nec (OFI); Insurance (ISR); Business services nec (OBS); Recreational and other services (ROS); Public Administration, Defense, Education, Health (OSG)</td><td>Partially (but not directly) modeled in EUCalc</td></tr>
</table>

The model simulations are computed using the GEMPACK economic modelling software (Harrison and Pearson, 1996, Horridge et al., 2018).

3 Baseline projection and implementation

The purpose of the baseline construction is to establish a likely business-as-usual (BAU) economic global scenario towards 2050, against which the transboundary effects of alternative EU decarbonization pathways can be simulated. In Deliverable 7.1 (Yu and Clora, 2018), we gather, analyze and compare annual GDP projections and the associated main drivers such as population, labor force (skilled and unskilled), capital stock, and total factor productivities for individual world countries, including all EU28 MS. After reviewing several recent model-based projections that can be considered as BAU, i.e. various "reference" scenarios and Shared Socioeconomic Pathway 2 (SSP2)[e] projections (Fricko et al., 2017, O'Neill et al., 2017), the following sources are selected:

- **GDP**: EU Reference Scenario 2016 (European Commission et al., 2016) and OECD-SSP2 (Dellink et al., 2017);
- **Population**: EUROSTAT, EU 2015 Ageing Report (European Commission (DG ECFIN) and Economic Policy Committee (AWG), 2014, European Commission (DG ECFIN) and Economic Policy Committee (AWG), 2015) and SSP2 projections for IIASA (Kc and Lutz, 2017);
- **Labor force**: EUROSTAT, EconMap2.4 (Fouré and Fontagné, 2016) and EU 2015 Ageing Report (European Commission (DG ECFIN) and Economic Policy Committee (AWG), 2015);
    - Total labor force is divided into skilled and unskilled, drawing from education projections obtained from Fouré and Fontagné (2016), which in turn are a processed version of the ones by Kc and Lutz (2017);
- **Capital stock**: EconMap2.4 (Fouré and Fontagné, 2016);
- **Total factor productivity** (TFP): EconMap2.4 (Fouré and Fontagné, 2016) and EU 2015 Ageing Report (European Commission (DG ECFIN) and Economic Policy Committee (AWG), 2015).

We use the GTAP-EUCalc model to project the world economy from 2011, which is the base year of the GTAP-E 9 database (Aguiar et al., 2016), to 2050, in line with the latest available literature (Bekkers et al., 2019, Fouré et al., 2013, Van der Mensbrugghe, 2015). We first project the economy to 2015, then to 2050 in 5-years steps. We target population and labor force projections by directly imposing shocks to the correspondent exogenous GTAP-EUCalc variables. To project GDP, we endogenize TFP in order to target the anticipated GDP levels. Additionally, we do not target directly the changes in capital stock, but opt for endogenizing it via the "Baldwin equation" (Francois and McDonald, 1996) in the model to effectively adopt a fixed savings rate closure with capital accumulation.

Besides implementing the macroeconomic projections, two other modeling features accounting for expected structural change for different economies are

[e] The Shared Socioeconomic Pathways describe alternative trends in the evolution of society and ecosystems from 2005 to 2100 at the world and regional levels. The SSPs are part of a framework that the climate change research community has adopted to facilitate the analysis of future climate impacts, vulnerabilities, adaptation, and mitigation. In SSP2, the world would undergo a transformation in which social, technological and economic trends do not deviate much from historical patterns observed over the past century.

added to the baseline projections. The first is about the differential productivity growth across sectors, whereas the second deals with fossil fuel prices and supply.

A differential in productivity growth between sectors is recognized in the literature and expected/assumed to continue in many model-based long run projection exercises (e.g. the ones mentioned above). In our work, we implement the differential sectoral productivity estimates of Bekkers et al. (2019), that in turn used the OECD Stan Database for Industrial Analysis and the EU KLEMS database. They estimate a 2.49 percentage points additional annual growth (with respect to average regional TFP growth) for agriculture, 1.51 for manufacture and -0.344 for services, at the world level. In order to map their estimations to the sectoral aggregation used in EUCalc, we calculate the differential sectoral productivities in each country/region as weighted averages of the estimated ones, using as weights the shares of value added in the different sectors.

Fossil fuel prices are typically assumed in long run projections to reflect future oil supplies. As in many other similar modeling exercises, projected changes in fossil fuel prices (IEA, 2012, IEA, 2017) are included in our baseline projections. This is implemented by endogenizing changes in the productivity of the oil, coal and gas sectors while targeting their respective prices, thereby making the supply of these fuels endogenously determined.

4 Selected EUCalc pathways simulated in GTAP-EUCalc

Following the interface between the EUCalc bottom-up core modules and the GTAP-EUCalc CGE model developed under Task 7.2 and reported in D7.2, sectoral inputs from the core modules are further implemented in GTAP-EUCalc (to be documented in Deliverable 8.6). This allows for complete EUCalc scenarios/pathways to be defined and simulated in GTAP-EUCalc. Below we discuss and define a library of representative pathways to be simulated in GTAP-EUCalc.

In fact, EUCalc can potentially generate billions of results, given the nearly infinite possibilities of combining its levers. This is not possible in GTAP-EUCalc, which requires a precise calibration of the modifications implemented. Additionally, CGE simulations are time-expensive, depending on the sectoral and regional aggregation and on a set of other parameters.

Owing to the size and computational complexities of GTAP-EUCalc, the trade module focuses on simulating the transboundary effects of a subset of the user-defined decarbonization pathways to represent the interesting and relevant scenarios identified during the co-design process.

In EUCalc Deliverable 7.2 (Baudry et al., 2018) three sets of potential scenarios to be simulated in GTAP-EUCalc were proposed:

- The first set simulates scenarios with identical ambition levels in all sectors and countries (i.e. 4 scenarios deriving from the 4 lever settings);
- The second set simulates different ambitions across the sectors, with sectoral ambition levels being kept the same across EU MS;
- The third set simulates scenarios with deviations by individual countries from the EU-wide ambition, i.e. each EU MS is assumed to deviate its level

settings (uniform across sectors) from the common level setting assumed for all other MS in the core scenario.

In the expert workshop held on November 22nd, 2019 (whose discussions and results are described in deliverable 7.3 (Yu and Clora, 2019)), this proposal was discussed with policymakers, representatives of EU and international institutions, and with economics experts in the field of international trade modeling. Commenting on the three proposed sets of scenarios, the experts emphasized the need to pay attention to the pathways that are likely to be interesting to the users, especially to policymakers. One suggestion was to aggregate along the MS dimension and focus mainly on sectoral decarbonization differences, effectively further reducing the number of scenarios to be modeled. Another suggestion was to model an even smaller set of scenarios and list them as pre-defined pathways in the EUCalc pathway explorer. These suggestions have been communicated, discussed and agreed upon within the EUCalc project consortium.

Based on these suggestions and discussions with experts and EUCalc partners, a number of representative pathways is formulated and simulated in GTAP-EUCalc. Given the baseline being the EUCalc pathway calibrated on the EU Reference Scenario, we currently specify 34 scenarios to be simulated in GTAP-EUCalc when all inputs from the sectoral WPs are finalized. Results from these simulations will be made accessible in the TPE. These pathways for which trade-related results are calculated can be divided into four sets, as shown in Table 4.1 and described below.

The first set of scenarios to be simulated corresponds to the pathways that specify uniform lever settings across all EU28+Switzerland countries for all relevant sectors, with identical ambition levels. More specifically, against the baseline scenario, each of these scenarios/pathways will correspond to a particular identical level setting for all levers in each and every sector across all EU28+Switzerland countries. There are four such scenarios/pathways, corresponding to the four ambition levels of the EUCalc model. These scenarios/pathways are designed to reflect a set of common decarbonization strategies across the member states and sectors. By varying the ambition levels across the different scenarios but keeping them uniform across member states and sectors, we illustrate how economic interdependencies between the EU and the ROW as well as within the EU would respond to these common ambition levels.

In the second set of scenarios, the levers in each pathway are assembled into two groups: demand-side and supply-side levers. Within a given pathway, all the demand-side levers are set at the same level, whereas all the supply-side levers are also set at the same level (albeit different from the level of the demand-side levers). Note that the pathways where all demand-side and supply-side levels are set at the same levels belong to the first set of pathways. This set of pathways explores different mixes of demand-side and supply-side emissions abatement actions, allowing the user to observe the differences in their relevance in terms of both GHG mitigation and transboundary flows.

The third set of scenarios is designed to explore potential sectoral sensitivities in evaluation decarbonization pathways in the EU context, as different sectors may have different emission-reduction potentials and/or may face different constraints in reaching a particular ambition level, or users may have different focus in exploring particular combinations of ambition levels across sectors. Therefore, even though an EU-wide decarbonization pathway is envisioned, such pathway may feature different lever settings for different sectors. In this set of scenarios, each pathway will contain a set of sectoral ambition levels imposed uniformly across the EU28+Switzerland (i.e. the ambition levels for any given sector is common across member countries); however, differences in ambition levels across sectors are allowed. As lever settings 2 and 3 represents respectively intermediate and high ambitions that are also considered to be "realistic"[f,g], they are used as the reference settings for all but one sectors whereas the remaining sector is allowed to deviate with a higher ambition. Furthermore, in these pathways, an additional constraint is imposed so that the demand and supply levers for the same sector are set at the same level (e.g. the demand side lever "travel" has be to set at the same level as the supply side lever "transportation"). For instance, all levers but "travel" and "transportation" (set at level 3) in pathway P17 are set at level 2, as shown in Table 4.1. Such a design allows users to appreciate the sensitivities of emission-reduction outcomes arising from changing the ambition level in both the demand and supply of a particular sector, conditional upon a common setting for other sectors.

The fourth and final set of pathways simulated in GTAP-EUCalc corresponds to the lever settings mimicking three of the European Long Term Strategies for a climate neutral economy (European Commission, 2018a, European Commission, 2018b). After EUCalc core modelers match their levers to represent sectoral actions and outcomes of EU LTSs, we use data derived from their lever positions (i.e. pathways) to simulate three scenarios:

- COMBO: it combines demand-side and supply-side actions without reaching though the maximum abatement ambition and full deployment of each technology modeled, aiming for net GHG emissions reduction (including LULUCF) in 2050 close to 90% compared to 1990;
- 1.5TECH: it aims to further increase the contribution of all the technology options (i.e. supply-side actions) in order to reach net zero emissions in 2050, thus pursuing efforts to achieve a 1.5C temperature change.
- 1.5LIFE: it relies less on the technology options of 1.5TECH, but assumes a drive by EU business and consumption patterns. In fact, it is underlined buy the increase in climate awareness of EU citizens, which translates in lifestyle changes and consumer choices more beneficial for the climate.

Most of the levers specified in the EUCalc model will be reflected in the pathways presented above; however, there are a few levers specified in EUCalc whose level settings other than the BAU levels are not compatible with the CGE framework. To avoid these incompatibilities, these levers are fixed to their BAU level in all the pathways presented in Table 4.1. In essence, the representative pathways only reflect scenarios of the following levers being set at their respective BAU levels, as follows:

- Population on B (BAU);
- Urbanization on B (BAU);
- Domestic food on B (BAU);
- Domestic production of manufacture products and materials on B (BAU);
- Land prioritization on A;
- Global mitigation effort on A (i.e. the rest of the world does not make any change in terms of mitigation efforts).

[f] This level is an intermediate scenario, more ambitious than business as usual but not reaching the full potential of available solutions.
[g] This level is considered very ambitious but realistic, given the current technology evolutions and the best practices observed in some geographical areas.

Table 4.1 - EUCalc pathways simulated in GTAP-EUCalc

Pathway	Demand-side groups of levers Travel	Homes	Diet	Cons[h]	Supply-side groups of levers Transp[i]	Bld[j]	Mnf[k]	Power	Land & Food	Biodiv[l]
p1	1	1	1	1	1	1	1	1	1	1
p2	2	2	2	2	2	2	2	2	2	2
p3	3	3	3	3	3	3	3	3	3	3
p4	4	4	4	4	4	4	4	4	4	4
Set 2 (demand vs supply efforts)										
p5	1	1	1	1	2	2	2	2	2	2
p6	1	1	1	1	3	3	3	3	3	3
p7	1	1	1	1	4	4	4	4	4	4
p8	2	2	2	2	1	1	1	1	1	1
p9	2	2	2	2	3	3	3	3	3	3
p10	2	2	2	2	4	4	4	4	4	4
p11	3	3	3	3	1	1	1	1	1	1
p12	3	3	3	3	2	2	2	2	2	2
p13	3	3	3	3	4	4	4	4	4	4
p14	4	4	4	4	1	1	1	1	1	1
p15	4	4	4	4	2	2	2	2	2	2
p16	4	4	4	4	3	3	3	3	3	3
Set 3 (D&S sectoral combo)										
p17	3	2	2	2	3	2	2	2	2	2
p18	2	3	2	2	2	3	2	2	2	2
p19	2	2	3	2	2	2	2	2	3	2
p20	2	2	2	3	2	2	3	2	2	2
p21	2	2	2	2	2	2	2	3	2	2
p22	4	2	2	2	4	2	2	2	2	2
p23	2	4	2	2	2	4	2	2	2	2
p24	2	2	4	2	2	2	2	2	4	2
p25	2	2	2	4	2	2	4	2	2	2
p26	2	2	2	2	2	2	2	4	2	2
p27	4	3	3	3	4	3	3	3	3	3
p28	3	4	3	3	3	4	3	3	3	3
p29	3	3	4	3	3	3	3	3	4	3
p30	3	3	3	4	3	3	4	3	3	3
p31	3	3	3	3	3	3	3	4	3	3
Set 4 (EU LTS)										
COMBO	COMBO	COMBO	COMBO	COMBO	COMBO	COMBO	COMBO	COMBO	COMBO	COMBO
1.5LIFE	1.5LIFE	1.5LIFE	1.5LIFE	1.5LIFE	1.5LIFE	1.5LIFE	1.5LIFE	1.5LIFE	1.5LIFE	1.5LIFE
1.5TECH	1.5TECH	1.5TECH	1.5TECH	1.5TECH	1.5TECH	1.5TECH	1.5TECH	1.5TECH	1.5TECH	1.5TECH

[h] Cons: consumption
[i] Transp: transport
[j] Bld: buildings
[k] Mnf: manufacture
[l] Biodiv: biodiversity

Additionally, some of the "land and food levers", of which the ABCD (rather than 1234) structure is based on a different rationale and is not directly tied to the emission efforts, albeit likely to follow similar patterns, are chosen to move with the above mentioned pathways according to the following concordances: A=1, B=2, C=3, D=4. In detail, these levers are "Climate Smart Livestock", "Climate Smart Cropping", "Climate Smart fisheries and aquaculture", "Hierarchy for biomass end-uses".

Finally, there are two lever positions included in the TPE but exert no influence on the part of the EUCalc results that are used as inputs for GTAP-EUCalc. These are "EU emissions after 2050", that sets the emission trend after 2050, and "discount factor", that determines cost actualization for the EUCalc cost calculations. As such, these levers are not considered in our simulations.

5 Module outputs shown in the TPE

A single simulation in GTAP-EUCalc generates a substantial amount of trade-related results which, if not properly presented to the EUCalc users, may be difficult to read and use. This would hamper one of the objectives of the EUCalc (i.e. accessibility) and would deprive EUCalc of part of its uniqueness in the family of calculators, i.e. computing trade effects arising from different EU decarbonization pathways. Therefore, a practical way to effectively exploit the results derived from GTAP-EUCalc is to further process the results to obtain some indicators that may be meaningful for users and policymakers and easy to present in the online EUCalc Transition Pathway Explorer.

A number of suggestions from the expert workshop are described in D7.3 (Yu and Clora, 2019). These proposals were considered when, together with the partners of Climate Media Factory, the more relevant indicators were selected.

For each of the pathways simulated in GTAP-EUCalc, four core results are shown in the TPE, namely:

- Aggregate EU+Switzerland exports, imports, and resulting trade balance, with 15 ROW countries/regions;
- EU+Switzerland trade with one aggregated ROW region for selected sectors;
- Compositions of intra-EU and extra-EU trade by EU MS and Switzerland;
- EU+Switzerland carbon leakages to ROW, total and for selected sectors, computed following the formula proposed by Kuik and Hofkes (2010).

The first set of results allows to observe the linkages of the aggregate EU28+Switzerland with individual external economies, accounting for overall changes in trade patterns and potential future economic partnerships emerging from EU decarbonization pathways.

The second series of results concern international trade in goods and services, from an "EU vs ROW" perspective. In fact, the change in the aggregate regional trade patterns are not sufficient to explain potential modifications to the world production structures and flows of goods and commodities. New EU consumption pattern and technological advancements will shape expansively the international trade of certain categories of commodities.

Even if the emission abatement ambitions in pathways simulated in GTAP-EUCalc are fixed at the EU-wide level (i.e. countries do not deviate from the overall EU decarbonization ambition), modifications are modeled at the EU country/region level. This is due to the fact that the same ambition level across the EU leads to different changes to demand and supply, both in absolute and in relative terms, at the country/regional granularity. In turn, these modifications affect differently the composition of trade flows (imports and exports) in each EU country/region, altering the shares of aggregate imports and exports from/to the other EU countries/regions (i.e. intra-EU trade) and from/to the rest of the world (i.e. extra-EU trade). The composition of intra-EU and extra-EU trade flows (both imports and exports) for each country/region provides additional insights into understanding how different EU decarbonization pathways would influence member states' dependence on the EU single market, as increased share of intra-EU trade signals increased dependence on the EU single market whereas decreased share points to the other direction. These results are included as the third series of trade results shown in the TPE.

Finally, as the EUCalc project aims at exploring EU decarbonization pathways, it is necessary to take into account how the rest of the world reacts to EU GHG abatement ambitions. In fact, efforts to reduce GHG emissions in a single country/region usually lead to increased emissions in other countries/regions. This phenomenon is called "carbon leakage" (even though it refers to all GHG emissions, not only to CO2). Current literature suggests that the carbon leakage rates vary widely across sectors and countries, as well as across different methodologies and models (Karp, 2011, Mattoo et al., 2009, Baylis et al., 2014). The last set of results, thus, allows the user to observe, in a general equilibrium framework, the degree of "emission effectiveness" of EU decarbonization pathways from a global emissions perspective.

5.1 Portfolio of GTAP-EUCalc Pathways

To illustrate the nature of the outputs generated by the GTAP-EUCalc model, we select two of the module results for two EUCalc pathways that have been simulated with the CGE model. Specifically, aggregate EU28+Switzerland exports, imports, and resulting trade balance with 15 ROW countries/regions, and EU28+Switzerland trade with one aggregated ROW region for selected sectors are shown. It should be noted that as with most long-term projections, results from the EUCalc model including those from WP7 are to be understood as "projections" rather than "predictions". These results are to be interpreted with care within the assumptions of the model and the inputs generated from the EUCalc core modules. Focus should be placed on the directions and relative magnitudes of the numerical results and the economic mechanisms behind the results, rather than the absolute size of the results.

The two pathways are simulated in GTAP-EUCalc in 2050 as counterfactuals against a baseline. The baseline scenario, in these calculations, mimics the EU-Reference Scenario (European Commission et al., 2016). In the first pathway denoted as P1, all levers are set at the lowest ambition levels (i.e. level 1), whereas in the second pathway P4, all levers are set at the highest ambition levels (i.e. level 4), representing the most ambitious decarbonization pathway in the EUCalc model. Note that P1 in fact represents a decarbonization scenario that is less ambitious than the EU-reference scenario.

The EUCalc core modules' data, for this illustrative purpose, are generated by the test version of the EUCalc model developed in January 2020 (prior to the final refined version).

Simulated changes in EU exports and imports (and the corresponding change in the trade balance) with other economies in the ROW from P1 and P4 are displayed in Figures 5.1 and 5.2, respectively. With very ambitious climate efforts in the EU (and no change in ROW climate efforts), the EU's balance of trade would improve with respect to Russia, the rest of Europe and other Former Soviet Union countries (FSU). Additionally, we observe a decrease in imports from Middle East and North Africa. These changes are mainly due to reduced EU demand for fossil fuels (e.g. oil and gas, EU has historically been a net importer). With other countries and regions (especially China and the US), it can be observed that there is a simultaneous decrease in exports and increase in imports, mainly driven by the deteriorating trade balance in sectors such as manufacturing and services. In contrast, lower ambitions as in P1, lead to an opposite situation where the EU's imports from countries and regions exporting fossil fuels (i.e. Russia, rest of Europe, other Former Soviet Union countries, Middle East and North Africa) increase and its trade balance with other major economies improves.

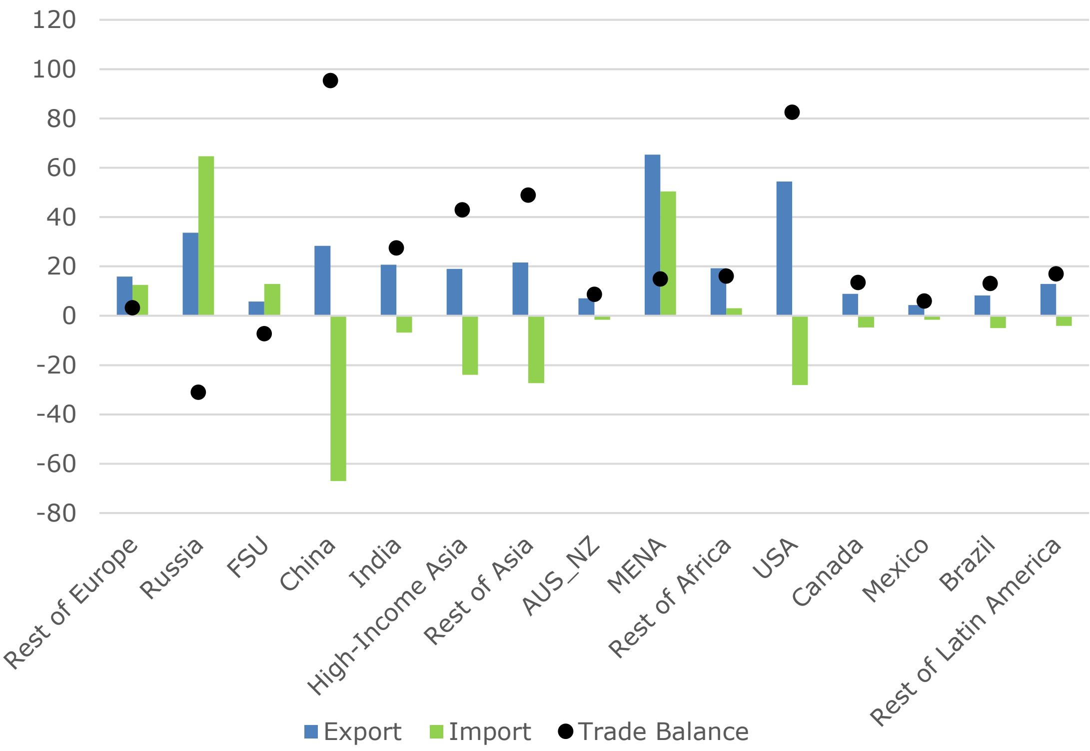

Figure 5.1 – Change with respect to the baseline in EU28 and Switzerland aggregate export, import and trade balance vs 15 ROW countries/regions in pathway P1 (i.e. all levers on 1). Billion (2011) USD.

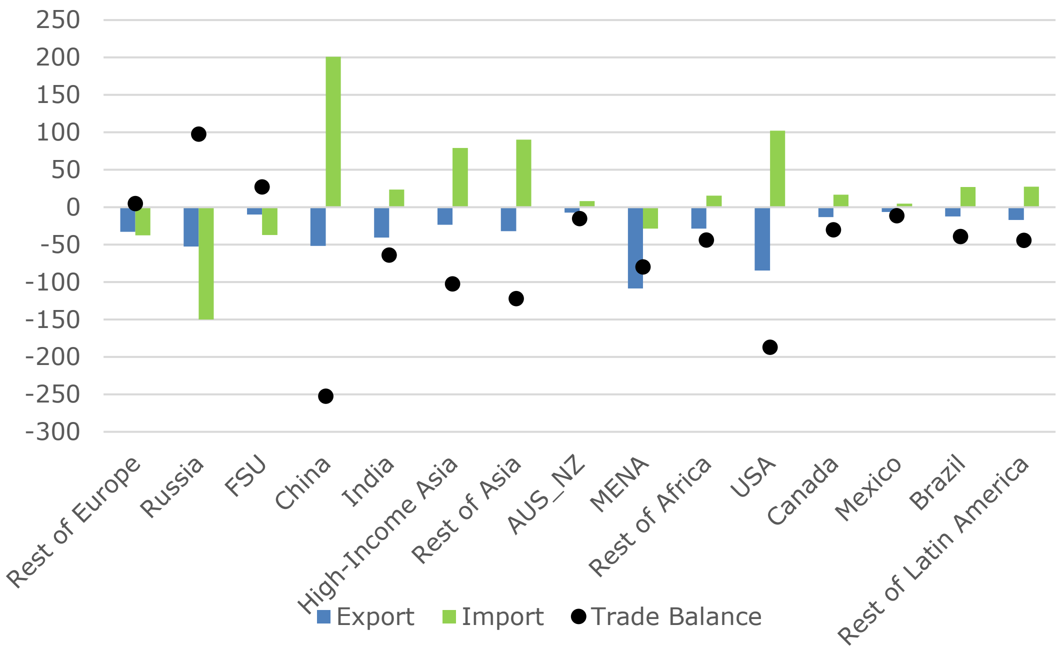

Figure 5.2 - Change with respect to the baseline in EU28 and Switzerland aggregate export, import and trade balance vs 15 ROW countries/regions in pathway P4 (i.e. all levers on 4). Billion (2011) USD.

To further understand the trade balance results, simulated change in EU exports, imports (and the implied trade balance) at the sectoral level are presented in Figures 5.3 and 5.4. In the highest mitigation ambition scenario (i.e. P4), changes in trade patterns and trade balances vary across sectors (Figure 5.4). For instance, the shift towards a more plant-based diet requires the EU to import more crops and grains from the ROW and to slightly reduce its imports of meat and other animal foods. Moreover, the EU's fossil fuel imports decrease, following its declining demand. In terms of trade volume, the more significant trade pattern changes are in the manufacturing and service sectors. With the decarbonization ambitions reducing manufacturing outputs, the EU would have to import more to make up for the shortfall in consumer and intermediate demands for manufacturing products. For the service sectors (excluding transportation services), increased demand arising from reallocated consumer budget towards less emission-intensive services (and away from emission-intensive products) would result in increased import demand for services. For transportation services, assumed technical enhancements in supplying transport services in the EU would lead to an improved trade balance with the ROW.

In contrast to the results from P4, if the EU reduces its mitigation efforts relative to the EU Reference Scenario, opposite changes in the EU's external trade balance at sectoral level are expected. According the results from P1 (Figure 5.3), demand for fossil fuels by consumers and industries would increase. Emission-intensive manufacturing production would go up and exceed domestic demand in the EU, thus allowing the EU's net exports to go up. As such, in this scenario the EU would improve its trade balance with the ROW in manufacturing products but increase its net fossil fuel imports. From the consumption side, as EU consumers are assumed to allocate more budget towards emission-intensive products, the EU's service exports would therefore increase.

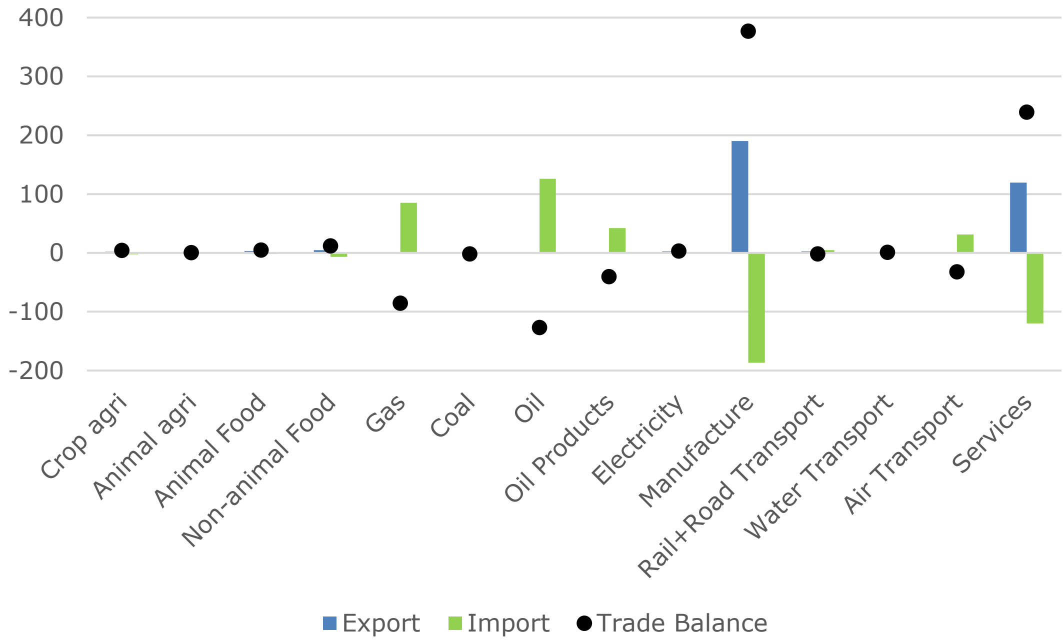

Figure 5.3 - Change with respect to the baseline in EU28 and Switzerland export import and trade vs an aggregated ROW region in pathway P1 (i.e. all levers on 1). Billion (2011) USD.

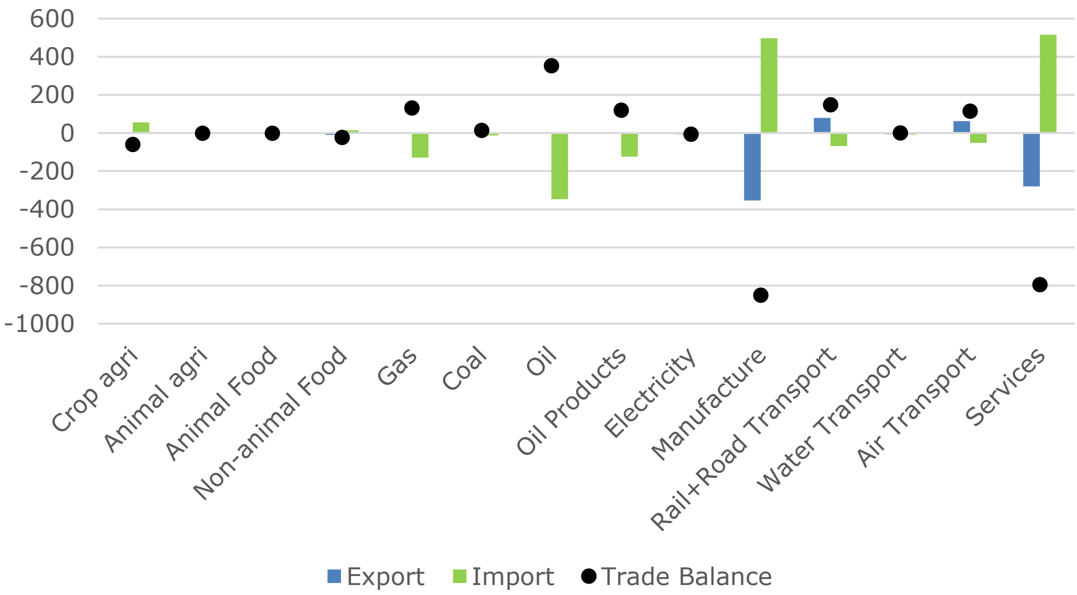

Figure 5.4 - Change with respect to the baseline in EU28 and Switzerland export import and trade vs an aggregated ROW region in pathway P4 (i.e. all levers on 4). Billion (2011) USD.

As expected, the decarbonization efforts contained in the illustrative pathways do alter the import, export and net trade positions across sectors and member states, particularly with respect to the key trading partners of EU28+Switzerland. These are the types of results that will be included in the TPE.

6 Conclusions

This deliverable documented the GTAP-EUCalc model and a portfolio of results for three preliminary pathways simulated with GTAP-EUCalc.

The scope of the "trade and transboundary flows" module (WP7) was presented, and an introduction to the GTAP framework, within which the GTAP-EUCalc model is developed, was offered. The key features of the GTAP-EUCalc model, specifically designed for the scope of the EUCalc project, were described in detail. The representative EUCalc pathways simulated with GTAP-EUCalc were then introduced and the rationale behind them was justified. Finally, the core outputs of the module were shown.

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8 Appendix – Detailed lever positions for pathways simulated with GTAP-EUCalc

In the tables below (8.1, 8.2, 8.3, 8.4, 8.5), within each group in the TPE, the lever settings are specified for the pathways simulated with the GTAP-EUCalc model. Pathways numbering is the same as in table 4.1.

For simplicity, the levers with an "ABCD" structure have been converted to a "1234" structure, by using the following concordances: A=1, B=2, C=3, D=4.

As explained in section 4, the following levers are fixed at their BAU levels:

- Population on B;
- Urbanization on B;
- Domestic food on B;
- Domestic production of manufacture products and materials on B;
- Land prioritization on A;
- Global mitigation effort on A (i.e. the rest of the world does not make any change in terms of mitigation efforts).

Two lever positions are uninfluential on the EUCalc results that are inputs for GTAP-EUCalc. These are "EU emissions after 2050", that sets the emission trend after 2050, and "discount factor", that determines cost actualization for the EUCalc cost calculations. In the tables included in this appendix, the independence between GTAP-EUCalc results and the lever position is signaled by an "x".

The detailed lever positions, especially for the baseline pathway (i.e. EU Reference Scenario) and for the predefined pathways (i.e. LTS Combo, LTS 1.5 Lifestyle, LTS 1.5 Technology), may be subject to adjustments in the final version of the model, due to improvements to computational speed and to the user-experience in the TPE.

Table 8.1 – Lever settings for pathways from P1 to P8

Group	**Lever**	**p1**	**p2**	**p3**	**p4**	**p5**	**p6**	**p7**	**p8**
Travel	Passenger distance	1	2	3	4	1	1	1	2
Travel	Mode of transport	1	2	3	4	1	1	1	2
Travel	Occupancy	1	2	3	4	1	1	1	2
Travel	Car own or hire	1	2	3	4	1	1	1	2
Homes	Living space per person	1	2	3	4	1	1	1	2
Homes	Percentage of cooled living space	1	2	3	4	1	1	1	2
Homes	Space cooling & heating	1	2	3	4	1	1	1	2
Homes	Appliances owned	1	2	3	4	1	1	1	2
Homes	Appliance use	1	2	3	4	1	1	1	2
Diet	Calories consumed	1	2	3	4	1	1	1	2
Diet	Type of diet	1	2	3	4	1	1	1	2
Consumption	Use of paper and packaging	1	2	3	4	1	1	1	2
Consumption	Product substitution rate	1	2	3	4	1	1	1	2
Consumption	Food waste at consumption level	1	2	3	4	1	1	1	2
Consumption	Freight distance	1	2	3	4	1	1	1	2
Transport	Passenger efficiency	1	2	3	4	2	3	4	1
Transport	Passenger technology	1	2	3	4	2	3	4	1
Transport	Freight efficiency	1	2	3	4	2	3	4	1
Transport	Freight technology share	1	2	3	4	2	3	4	1
Transport	Freight mode	1	2	3	4	2	3	4	1
Transport	Freight utilization rate	1	2	3	4	2	3	4	1
Transport	Fuel mix	1	2	3	4	2	3	4	1
Buildings	Building envelope	1	2	3	4	2	3	4	1
Buildings	District heating share	1	2	3	4	2	3	4	1
Buildings	Technology and fuel share	1	2	3	4	2	3	4	1
Buildings	Heating and cooling efficiency	1	2	3	4	2	3	4	1
Buildings	Appliances efficiency	1	2	3	4	2	3	4	1
Manufacturing	Material efficiency	1	2	3	4	2	3	4	1
Manufacturing	Material switch	1	2	3	4	2	3	4	1
Manufacturing	Technology efficiency	1	2	3	4	2	3	4	1
Manufacturing	Energy efficiency	1	2	3	4	2	3	4	1
Manufacturing	Fuel mix	1	2	3	4	2	3	4	1
Manufacturing	Carbon Capture in manufacturing	1	1	1	1	1	1	1	1
Manufacturing	Carbon Capture to fuel	1	1	1	1	1	1	1	1
Power	Coal phase out	1	2	3	4	2	3	4	1
Power	Carbon Capture ratio in power	1	1	1	1	1	1	1	1
Power	Nuclear	1	2	3	4	2	3	4	1
Power	Wind	1	2	3	4	2	3	4	1
Power	Solar	1	2	3	4	2	3	4	1
Power	Hydro, geo & tidal	1	2	3	4	2	3	4	1
Power	Balancing strategies	1	2	3	4	2	3	4	1
Power	Charging profiles	1	2	3	4	2	3	4	1
Land and food	Climate smart crop production	1	2	3	4	2	3	4	1
Land and food	Climate smart livestock	1	2	3	4	2	3	4	1
Land and food	Bioenergy capacity	1	2	3	4	2	3	4	1
Land and food	Alternative protein source	1	2	3	4	2	3	4	1
Land and food	Forestry practices	1	2	3	4	2	3	4	1
Land and food	Land management	1	2	3	4	2	3	4	1
Land and food	Hierarchy for biomass end-uses	1	2	3	4	2	3	4	1
Water and biodiversity	Biodiversity	1	2	3	4	2	3	4	1
Water and biodiversity	Land prioritization	1	1	1	1	1	1	1	1
Demographics & long-term	Population	2	2	2	2	2	2	2	2
Demographics & long-term	Urban population	2	2	2	2	2	2	2	2
Demographics & long-term	EU emissions after 2050	x	x	x	x	x	x	x	x
Domestic production	Domestic food production	2	2	2	2	2	2	2	2
Domestic production	Domestic product output	2	2	2	2	2	2	2	2
Domestic production	Domestic material production	2	2	2	2	2	2	2	2
Constraints	Global mitigation effort	1	1	1	1	1	1	1	1
Constraints	Discount factor	x	x	x	x	x	x	x	x

Table 8.2 - Lever settings for pathways from P9 to P16

Group	Lever	p9	p10	p11	p12	p13	p14	p15	p16
Travel	Passenger distance	2	2	3	3	3	4	4	4
Travel	Mode of transport	2	2	3	3	3	4	4	4
Travel	Occupancy	2	2	3	3	3	4	4	4
Travel	Car own or hire	2	2	3	3	3	4	4	4
Homes	Living space per person	2	2	3	3	3	4	4	4
Homes	Percentage of cooled living space	2	2	3	3	3	4	4	4
Homes	Space cooling & heating	2	2	3	3	3	4	4	4
Homes	Appliances owned	2	2	3	3	3	4	4	4
Homes	Appliance use	2	2	3	3	3	4	4	4
Diet	Calories consumed	2	2	3	3	3	4	4	4
Diet	Type of diet	2	2	3	3	3	4	4	4
Consumption	Use of paper and packaging	2	2	3	3	3	4	4	4
Consumption	Product substitution rate	2	2	3	3	3	4	4	4
Consumption	Food waste at consumption level	2	2	3	3	3	4	4	4
Consumption	Freight distance	2	2	3	3	3	4	4	4
Transport	Passenger efficiency	3	4	1	2	4	1	2	3
Transport	Passenger technology	3	4	1	2	4	1	2	3
Transport	Freight efficiency	3	4	1	2	4	1	2	3
Transport	Freight technology share	3	4	1	2	4	1	2	3
Transport	Freight mode	3	4	1	2	4	1	2	3
Transport	Freight utilization rate	3	4	1	2	4	1	2	3
Transport	Fuel mix	3	4	1	2	4	1	2	3
Buildings	Building envelope	3	4	1	2	4	1	2	3
Buildings	District heating share	3	4	1	2	4	1	2	3
Buildings	Technology and fuel share	3	4	1	2	4	1	2	3
Buildings	Heating and cooling efficiency	3	4	1	2	4	1	2	3
Buildings	Appliances efficiency	3	4	1	2	4	1	2	3
Manufacturing	Material efficiency	3	4	1	2	4	1	2	3
Manufacturing	Material switch	3	4	1	2	4	1	2	3
Manufacturing	Technology efficiency	3	4	1	2	4	1	2	3
Manufacturing	Energy efficiency	3	4	1	2	4	1	2	3
Manufacturing	Fuel mix	3	4	1	2	4	1	2	3
Manufacturing	Carbon Capture in manufacturing	1	1	1	1	1	1	1	1
Manufacturing	Carbon Capture to fuel	1	1	1	1	1	1	1	1
Power	Coal phase out	3	4	1	2	4	1	2	3
Power	Carbon Capture ratio in power	1	1	1	1	1	1	1	1
Power	Nuclear	3	4	1	2	4	1	2	3
Power	Wind	3	4	1	2	4	1	2	3
Power	Solar	3	4	1	2	4	1	2	3
Power	Hydro, geo & tidal	3	4	1	2	4	1	2	3
Power	Balancing strategies	3	4	1	2	4	1	2	3
Power	Charging profiles	3	4	1	2	4	1	2	3
Land and food	Climate smart crop production	3	4	1	2	4	1	2	3
Land and food	Climate smart livestock	3	4	1	2	4	1	2	3
Land and food	Bioenergy capacity	3	4	1	2	4	1	2	3
Land and food	Alternative protein source	3	4	1	2	4	1	2	3
Land and food	Forestry practices	3	4	1	2	4	1	2	3
Land and food	Land management	3	4	1	2	4	1	2	3
Land and food	Hierarchy for biomass end-uses	3	4	1	2	4	1	2	3
Water and biodiversity	Biodiversity	3	4	1	2	4	1	2	3
Water and biodiversity	Land prioritization	1	1	1	1	1	1	1	1
Demographics & long-term	Population	2	2	2	2	2	2	2	2
Demographics & long-term	Urban population	2	2	2	2	2	2	2	2
Demographics & long-term	EU emissions after 2050	x	x	x	x	x	x	x	x
Domestic production	Domestic food production	2	2	2	2	2	2	2	2
Domestic production	Domestic product output	2	2	2	2	2	2	2	2
Domestic production	Domestic material production	2	2	2	2	2	2	2	2
Constraints	Global mitigation effort	1	1	1	1	1	1	1	1
Constraints	Discount factor	x	x	x	x	x	x	x	x

Table 8.3 - Lever settings for pathways from P17 to P24

Group	Lever	p17	p18	p19	p20	p21	p22	p23	p24
Travel	Passenger distance	3	2	2	2	2	4	2	2
Travel	Mode of transport	3	2	2	2	2	4	2	2
Travel	Occupancy	3	2	2	2	2	4	2	2
Travel	Car own or hire	3	2	2	2	2	4	2	2
Homes	Living space per person	2	3	2	2	2	2	4	2
Homes	Percentage of cooled living space	2	3	2	2	2	2	4	2
Homes	Space cooling & heating	2	3	2	2	2	2	4	2
Homes	Appliances owned	2	3	2	2	2	2	4	2
Homes	Appliance use	2	3	2	2	2	2	4	2
Diet	Calories consumed	2	2	3	2	2	2	2	4
Diet	Type of diet	2	2	3	2	2	2	2	4
Consumption	Use of paper and packaging	2	2	2	3	2	2	2	2
Consumption	Product substitution rate	2	2	2	3	2	2	2	2
Consumption	Food waste at consumption level	2	2	2	3	2	2	2	2
Consumption	Freight distance	2	2	2	3	2	2	2	2
Transport	Passenger efficiency	3	2	2	2	2	4	2	2
Transport	Passenger technology	3	2	2	2	2	4	2	2
Transport	Freight efficiency	3	2	2	2	2	4	2	2
Transport	Freight technology share	3	2	2	2	2	4	2	2
Transport	Freight mode	3	2	2	2	2	4	2	2
Transport	Freight utilization rate	3	2	2	2	2	4	2	2
Transport	Fuel mix	3	2	2	2	2	4	2	2
Buildings	Building envelope	2	3	2	2	2	2	4	2
Buildings	District heating share	2	3	2	2	2	2	4	2
Buildings	Technology and fuel share	2	3	2	2	2	2	4	2
Buildings	Heating and cooling efficiency	2	3	2	2	2	2	4	2
Buildings	Appliances efficiency	2	3	2	2	2	2	4	2
Manufacturing	Material efficiency	2	2	2	3	2	2	2	2
Manufacturing	Material switch	2	2	2	3	2	2	2	2
Manufacturing	Technology efficiency	2	2	2	3	2	2	2	2
Manufacturing	Energy efficiency	2	2	2	3	2	2	2	2
Manufacturing	Fuel mix	2	2	2	3	2	2	2	2
Manufacturing	Carbon Capture in manufacturing	1	1	1	1	1	1	1	1
Manufacturing	Carbon Capture to fuel	1	1	1	1	1	1	1	1
Power	Coal phase out	2	2	2	2	3	2	2	2
Power	Carbon Capture ratio in power	1	1	1	1	1	1	1	1
Power	Nuclear	2	2	2	2	3	2	2	2
Power	Wind	2	2	2	2	3	2	2	2
Power	Solar	2	2	2	2	3	2	2	2
Power	Hydro, geo & tidal	2	2	2	2	3	2	2	2
Power	Balancing strategies	2	2	2	2	3	2	2	2
Power	Charging profiles	2	2	2	2	3	2	2	2
Land and food	Climate smart crop production	2	2	3	2	2	2	2	4
Land and food	Climate smart livestock	2	2	3	2	2	2	2	4
Land and food	Bioenergy capacity	2	2	3	2	2	2	2	4
Land and food	Alternative protein source	2	2	3	2	2	2	2	4
Land and food	Forestry practices	2	2	3	2	2	2	2	4
Land and food	Land management	2	2	3	2	2	2	2	4
Land and food	Hierarchy for biomass end-uses	2	2	3	2	2	2	2	4
Water and biodiversity	Biodiversity	2	2	2	2	2	2	2	2
Water and biodiversity	Land prioritization	1	1	1	1	1	1	1	1
Demographics & long-term	Population	2	2	2	2	2	2	2	2
Demographics & long-term	Urban population	2	2	2	2	2	2	2	2
Demographics & long-term	EU emissions after 2050	x	x	x	x	x	x	x	x
Domestic production	Domestic food production	2	2	2	2	2	2	2	2
Domestic production	Domestic product output	2	2	2	2	2	2	2	2
Domestic production	Domestic material production	2	2	2	2	2	2	2	2
Constraints	Global mitigation effort	1	1	1	1	1	1	1	1
Constraints	Discount factor	x	x	x	x	x	x	x	x

Table 8.4 - Lever settings for pathways from P25 to P31

Group	Lever	p25	p26	p27	p28	p29	p30	p31
Travel	Passenger distance	2	2	4	3	3	3	3
Travel	Mode of transport	2	2	4	3	3	3	3
Travel	Occupancy	2	2	4	3	3	3	3
Travel	Car own or hire	2	2	4	3	3	3	3
Homes	Living space per person	2	2	3	4	3	3	3
Homes	Percentage of cooled living space	2	2	3	4	3	3	3
Homes	Space cooling & heating	2	2	3	4	3	3	3
Homes	Appliances owned	2	2	3	4	3	3	3
Homes	Appliance use	2	2	3	4	3	3	3
Diet	Calories consumed	2	2	3	3	4	3	3
Diet	Type of diet	2	2	3	3	4	3	3
Consumption	Use of paper and packaging	4	2	3	3	3	4	3
Consumption	Product substitution rate	4	2	3	3	3	4	3
Consumption	Food waste at consumption level	4	2	3	3	3	4	3
Consumption	Freight distance	4	2	3	3	3	4	3
Transport	Passenger efficiency	2	2	4	3	3	3	3
Transport	Passenger technology	2	2	4	3	3	3	3
Transport	Freight efficiency	2	2	4	3	3	3	3
Transport	Freight technology share	2	2	4	3	3	3	3
Transport	Freight mode	2	2	4	3	3	3	3
Transport	Freight utilization rate	2	2	4	3	3	3	3
Transport	Fuel mix	2	2	4	3	3	3	3
Buildings	Building envelope	2	2	3	4	3	3	3
Buildings	District heating share	2	2	3	4	3	3	3
Buildings	Technology and fuel share	2	2	3	4	3	3	3
Buildings	Heating and cooling efficiency	2	2	3	4	3	3	3
Buildings	Appliances efficiency	2	2	3	4	3	3	3
Manufacturing	Material efficiency	4	2	3	3	3	4	3
Manufacturing	Material switch	4	2	3	3	3	4	3
Manufacturing	Technology efficiency	4	2	3	3	3	4	3
Manufacturing	Energy efficiency	4	2	3	3	3	4	3
Manufacturing	Fuel mix	4	2	3	3	3	4	3
Manufacturing	Carbon Capture in manufacturing	1	1	1	1	1	1	1
Manufacturing	Carbon Capture to fuel	1	1	1	1	1	1	1
Power	Coal phase out	2	4	3	3	3	3	4
Power	Carbon Capture ratio in power	1	1	1	1	1	1	1
Power	Nuclear	2	4	3	3	3	3	4
Power	Wind	2	4	3	3	3	3	4
Power	Solar	2	4	3	3	3	3	4
Power	Hydro, geo & tidal	2	4	3	3	3	3	4
Power	Balancing strategies	2	4	3	3	3	3	4
Power	Charging profiles	2	4	3	3	3	3	4
Land and food	Climate smart crop production	2	2	3	3	4	3	3
Land and food	Climate smart livestock	2	2	3	3	4	3	3
Land and food	Bioenergy capacity	2	2	3	3	4	3	3
Land and food	Alternative protein source	2	2	3	3	4	3	3
Land and food	Forestry practices	2	2	3	3	4	3	3
Land and food	Land management	2	2	3	3	4	3	3
Land and food	Hierarchy for biomass end-uses	2	2	3	3	4	3	3
Water and biodiversity	Biodiversity	2	2	3	3	3	3	3
Water and biodiversity	Land prioritization	1	1	1	1	1	1	1
Demographics & long-term	Population	2	2	2	2	2	2	2
Demographics & long-term	Urban population	2	2	2	2	2	2	2
Demographics & long-term	EU emissions after 2050	x	x	x	x	x	x	x
Domestic production	Domestic food production	2	2	2	2	2	2	2
Domestic production	Domestic product output	2	2	2	2	2	2	2
Domestic production	Domestic material production	2	2	2	2	2	2	2
Constraints	Global mitigation effort	1	1	1	1	1	1	1
Constraints	Discount factor	x	x	x	x	x	x	x

Table 8.5 - Lever settings for pathways EUREF, LTS Combo, LTS 1.5 Lifestyle, LTS 1.5 Technology

Group	Lever	EUREF	COMBO	15LFE	15TECH
Travel	Passenger distance	1	1.2	1.5	2
Travel	Mode of transport	1.3	2.9	2.1	3.4
Travel	Occupancy	1.3	2.8	2.4	3.7
Travel	Car own or hire	1.3	3	2	3.5
Homes	Living space per person	1.5	1.5	1.5	2
Homes	Percentage of cooled living space	2	2	2	2
Homes	Space cooling & heating	1	2	2	2
Homes	Appliances owned	1.8	1.8	1.8	1.8
Homes	Appliance use	3	1.8	1.8	1.8
Diet	Calories consumed	2	2	2	2
Diet	Type of diet	1	1	1	2
Consumption	Use of paper and packaging	2	2	2	2
Consumption	Product substitution rate	1	1	1	1
Consumption	Food waste at consumption level	3	3	3	3
Consumption	Freight distance	1.1	2.8	1.9	3.6
Transport	Passenger efficiency	1.3	3	3.8	2.8
Transport	Passenger technology	1.1	3.2	3.5	3.1
Transport	Freight efficiency	1.1	3	3.4	2.6
Transport	Freight technology share	1.1	3.3	3.7	2.9
Transport	Freight mode	1.3	2.8	2.3	3.3
Transport	Freight utilization rate	1.3	2.9	2.6	3.1
Transport	Fuel mix	1.3	2.7	2	3.5
Buildings	Building envelope	2	3	3	3
Buildings	District heating share	2	2	2	2
Buildings	Technology and fuel share	2	2.5	3	3
Buildings	Heating and cooling efficiency	2	3	3	3
Buildings	Appliances efficiency	2	3	3	3
Manufacturing	Material efficiency	1.5	2.7	2.8	4
Manufacturing	Material switch	1.5	2.6	2.9	3.5
Manufacturing	Technology efficiency	1.5	2.5	2.9	4
Manufacturing	Energy efficiency	1.5	2.7	2.9	4
Manufacturing	Fuel mix	1.5	2.5	2.9	3.6
Manufacturing	Carbon Capture in manufacturing	1	2.6	2.8	3.6
Manufacturing	Carbon Capture to fuel	1	1	1	1
Power	Coal phase out	3	3	4	4
Power	Carbon Capture ratio in power	1	2	3	3
Power	Nuclear	3	4	4	4
Power	Wind	2	2.6	3.1	2.4
Power	Solar	2	2.6	3.1	2.4
Power	Hydro, geo & tidal	2	2	2	1.9
Power	Balancing strategies	1	1	3	2
Power	Charging profiles	1	3	4	3
Land and food	Climate smart crop production	2	2	2	3
Land and food	Climate smart livestock	2	2	2	3
Land and food	Bioenergy capacity	1	3	3	2
Land and food	Alternative protein source	1	1	1	1
Land and food	Forestry practices	1	1	1	1
Land and food	Land management	1	1	1	1
Land and food	Hierarchy for biomass end-uses	2	3	3	2
Water and biodiversity	Biodiversity	1	1	1	1
Water and biodiversity	Land prioritization	1	1	1	1
Demographics & long-term	Population	2	2	2	2
Demographics & long-term	Urban population	2	2	2	2
Demographics & long-term	EU emissions after 2050	1	1	1	1
Domestic production	Domestic food production	2	2	2	2
Domestic production	Domestic product output	2	2	2	2
Domestic production	Domestic material production	2	2	2	2
Constraints	Global mitigation effort	1	1	1	1
Constraints	Discount factor	1	1	1	1